Victoria's rainforests and the potential impacts of a changing climate

Maggie Riddington

School of Life and Environmental Sciences, Deakin University, Burwood Campus,
221 Burwood Highway, Burwood, Victoria 3125

Abstract

Though once prolific across the continent, the rainforests of Australia have receded to a fraction of their original extent. In Victoria, rainforests account for as little as 0.14% of the state, and a disproportionately large number of species are found within them. As rainforests are found where temperatures are mild and rainfall is consistent and high, the prospect of a changing climate threatens their structure, function, and possibly their existence. This desktop study investigated climate predictions based on various emissions scenarios, and compared them to current characteristics and requirements of Victoria's cool temperate rainforests to determine the impact they could have on these forests, particularly the most iconic species found within them, such as *Atherosperma moschatum* Labill. c Labill. and *Nothofagus cunninghamii* (Hook.) Oerst, which may be most at risk to the effects of climate change, particularly fire. The study explores the impact a changing climate may have on the rainforests of Victoria and focuses on some key canopy species of cool temperate rainforest. It also brings into light the need for more research into climate change in conjunction with other key ecosystem factors such as soil type, elevation and human disturbance. (*The Victorian Naturalist* **131**(6), 2014, 209-218)

Key words: Climate change, cool temperate rainforest, *Nothofagus cunninghamii*, *Atherosperma moschatum*

Introduction

The roots of today's rainforests have been traced back to when Australia was part of the Gondwanan super-continent (100 mya) (Peel 1999). At that time, most of Australia was covered by rainforest. Since then, however, the distribution and dominance of rainforest has varied as Australia broke free of the super-continent and underwent numerous climatic changes (Beadle 1981). It is thought that the Australian continent moved 30° of latitude north during the Cretaceous and Tertiary, causing significant climatic changes (Beadle 1981). The ancient climatic regime to which rainforests were adapted, i.e. dependable, high rainfall and low fire frequency, is now rare and Australia's rainforests have receded to isolated, protected patches (Peel 1999).

Rainforests can be defined according to rainfall, atmospheric conditions, soil and local topography. For the purpose of this article, a rainforest is characterised by a closed tree canopy that distinguishes it from other vegetation in areas of high rainfall, generally comprises many taxa and, perhaps most significantly, has canopy species with the ability to regenerate without the need for broad-scale disturbance (Busby and Brown 1994).

Five main types of rainforest occur in Victoria. Cool temperate rainforest occurs in the Otway Ranges, Wilsons Promontory, the Strzelecki Ranges, the Central Highlands and some parts of East Gippsland (Peel 1999). At lower elevations, the gradient from cool temperate rainforest to tall eucalypt forest includes a 'mixed' ecotone of cool temperate mixed forest. This blurred boundary from one vegetation type to another is unique in itself; it is characterised by an understorey of rainforest species with a eucalypt canopy (Busby and Brown 1994). Warm temperate rainforests are floristically rich and are most common east of the Mitchell River in East Gippsland, although other communities may be found in the Strzeleckis and at Wilsons Promontory (Peel 1999). Gallery rainforest is found in river valleys of East Gippsland, and dry rainforest, the least common of the five Victorian rainforest types, is found only in areas east of the Mitchell River and, due to its habitat, is relatively removed from fire danger (Peel 1999).

Rainforests occur as far west as Cape Otway and reach into the far corners of East Gippsland. They occupy less than 0.14% of Victoria, yet a disproportionate number of rare or threatened species may be found within them (Peel 1999).

They have high levels of biodiversity, are valued for their water provision and are becoming increasingly more important for carbon capture and storage (Lindenmayer *et al.* 2011; Mackey *et al.* 2008). With this knowledge, it makes the need to protect them an even greater priority; however, climate change is a looming threat to the viability of rainforests in the future.

The distribution, health and abundance of Australian vegetation depend on consistencies in temperature, rainfall, fire regime and soil fertility as well as other factors (Beadle 1981). It is predicted that climate change will significantly alter three of these four parameters. Temperatures are predicted to continue to rise, annual rainfall will decrease and extreme weather events such as fire will increase in frequency and intensity (VCC 2008). Victoria's rainforests are particularly sensitive to such changes in the environment; key rainforest species such as *Atherosperma moschatum* Labill. c Labill. have low photosynthetic tolerance in high temperatures (Read and Busby 1990). Fire and climate are strongly correlated with the geographical limits of the prominent rainforest canopy species *Nothofagus cunninghamii* (Hook.) Oerst (Busby 1986). What will become of Victoria's rainforests?

In 2008, the Victorian Government released a summary of climate change predictions for Victoria prepared by CSIRO. This summary predicts that Victoria will become warmer and drier in the near future as a result of climate change. Victoria will experience more rapid warming than global trends, with a predicted temperature increase of 0.8°C per annum by 2030 (VCC 2008). The number of hot days will increase in frequency and intensity, more so in inland regions than coastal regions (VCC 2008a). Annual rainfall is expected to decrease by 4% by 2030 and 6% by 2070 (VCC 2008). Not only will the state become drier, but drought risk will increase by 10–80% by 2070 due to enhanced evaporation (VCC 2008a). Perhaps most threatening to Victoria's rainforests will be the predicted increase in fire frequency and intensity due to climate change. The warmer, drier climate will result in a greater number of 'extreme' fire danger days. By 2020, the number of 'extreme' fire days is estimated to increase by 5–40%, relative to the climate of 1974 to 2003 (VCC 2008). Under a low-emissions scenario, by 2050, the number of fire days may increase from 15–25% but under a higher-emissions scenario the risk of extreme fire danger days may increase by a staggering 120–230% (VCC 2008). This is grim news for Victoria, and especially for its unique rainforests. Some areas will be more at risk than others; for instance with the varying predictions for coastal versus inland sites, the rainforest of the Otways may be less affected than the rainforest of the Central Highlands.

The effect of climate change on the rainforests of Victoria

The summary of predictions for climate change in Victoria divides the state into ten main regions (VCC 2008). Climate change will affect different parts of the state to different degrees and in varying ways. The five different rainforest types found across the state have different requirements and tolerances for rainfall, fire frequency and temperatures. Therefore, the impacts of climate change on Victoria's rainforests will vary not only according to the specific requirements of the rainforest type itself, but also with regard to its locations throughout the state.

Each rainforest type found in Victoria will experience raised temperatures and reduced rainfall by 2030 and 2070 compared to current levels; while cool temperate rainforest is found in more regions than any other rainforest type, curiously, it has more restricting climate limitations than other rainforest types. This means that changes in climate will significantly affect cool temperate rainforests. By 2030, cool temperate rainforests across the state may experience temperature increases averaging 0.8°C per year; and 3.6% less rainfall than current levels. The higher emission scenario for 2070 could see temperature rises in areas of cool temperate rainforests as high as 2.6°C per annum; and 10.6% less rainfall than present-day levels (Table 1).

To compare the effect climate change will have on temperatures and rainfall levels in the near future with regard to the rainforests of Victoria, the differences between current levels and predicted levels are expressed in percentage form in Table 2. In 2070, gallery and dry rainforests

Table 1. Current and predicted future temperatures and annual rainfall in Victoria's rainforests (after Peel, 1999; VCC 2011a; VCC 2011b; VCC 2011c; VCC 2011d; VCC 2011e).

Rainforest Type	Locations	Current Temps Winter/Summer*	2030 Temps	2070 Temps - Lower/higher emissions	Current rainfall (mm)	2030 rainfall	2070 rainfall
Cool Temperate		**0-6°C/6-12°C**			**1200-2000mm**		
	North East	1.4°C/11.2°C	+0.9°C	+1.5°/2.9°C	1089mm	-3%	-5%/-10%
	Otways	5°C/11.6°C	+0.8°C	+1.3°C/2.4°C	773mm	-4%	-6%/-12%
	Wilson's Promontory	4°C/11.5°C	+0.8°C	+1.4°C/2.6°C	926mm	-4%	-6%/-11%
	Strzeleckis	4°C/11.5°C	+0.8°C	+1.4°C/2.6°C	926mm	-4%	-6%/-11%
	Central Highlands	4.6°C/12°C	+0.8°C	+1.3°C/2.6°C	864mm	-4%	-6%/-11%
	East Gippsland	2.3°C/11.1°C	+0.8°C	+1.4°C/2.7°C	924mm	-3%	-5%/-9%
Cool Temperate		**0-6°C/6-12°C**			**1200 - 2000mm**		
Mixed Forest	Central Highlands	4.6°C/12°C	+0.8°C	+1.3°C/2.6°C	864mm	-4%	-6%/-11%
	East Gippsland	2.3°C/11.1°C	+0.8°C	+1.4°C/2.7°C	924mm	-3%	-5%/-9%
Warm Temperate		**4.8°C/14.1°C**			**734-1200mm**		
	Strzeleckis	4°C/11.5°C	+0.8°C	+1.4°C/2.6°C	864mm	-4%	-6%/-11%
	East Gippsland	2.3°C/11.1°C	+0.8°C	+1.4°C/2.7°C	924mm	-3%	-5%/-9%
Gallery Rainforest		**4.8°C/14.1°C**			**734-1200mm**		
	East Gippsland	2.3°C/11.1°C	+ 0.8°C	+1.4°C/2.7°C	924mm	-3%	-5%/-9%
	Dry Rainforest	1.9°C/14.5°C			716-994mm		
	East Gippsland	2.3°C/11.1°C	+0.8°C	+1.4°C/2.7°C	924mm	-3%	-5%/-9%

Table 2. The percentage differences in average temperatures and annual rainfall across Victoria's rainforest types according to lower emissions scenarios for 2030 and 2070 for the state of Victoria.

	Average Temperature Increase by %				**Average difference in annual rainfall by %**
	2030		2070		2070
Rainforest type	Winter	Summer	Winter	Summer	Lower emissions
Cool temperate rainforest	23	7	39-74	12-23	-28
Cool temperate mixed forest	23	7	39-74	12-23	-30
Warm temperate rainforest	25	7	44-86	12-24	14
Gallery rainforest	35	7	61-117	13-21	20
Dry rainforest	35	7	61-117	13-21	23

may experience winter temperature increases of 61% above current temperatures under a lower emissions scenario whereby CO^2 emissions increase until 2040, at which point they decline (VCC 2008). This is the minimum increase we can expect in 2070. Other rainforest types will experience an increase of about 40–44%. In summer, all rainforest types will experience a 12–13% temperature rise from current-day levels (Table 2).

Rainforests are characterised by fairly dependable temperature and rainfall thresholds. Cool temperate rainforests and cool temperate mixed forests currently require high to very high annual rainfall of 1200–2000 mm (Peel 1999). Warm temperate, dry and gallery rainforests require moderate to high levels of annual rainfall of 716–1200 mm (Peel 1999). Based on lower emissions scenario predictions for 2070, dry, gallery and warm temperate rainforest will be sitting well within the thresholds of their annual rainfall requirements (Fig. 1). Cool temperate rainforest and cool temperate mixed forest, on the other hand, will receive between 28 and 30% (on average) less than their minimum annual rainfall requirement (Fig. 1).

Changing fire regimes

Dry rainforest resists fire due to its location, while the proximity to fire-shielding landscape elements like estuaries or lakes often protects warm temperate rainforests from fire (Peel 1999). Unlike dry and warm temperate rainforest, the fire resistance of cool temperate rainforest is dependent on impermanent defences such as temperature and moisture levels, which make them the most vulnerable to climate change. Cool temperate rainforests form a closed canopy after long periods without disturbance, which then serves to foster a humid interior that not only keeps the forest moist, but also aids in the rapid decomposition of fine fuels (Busby and Brown 1994). Should rainfall levels fall and temperatures rise, this protective humidity eventually will decline, fuel loads will increase and any lichen-covered stags that stand in the forest will dry out, making them a flammable opening in the canopy (Busby and Brown 1994). As rainforests are characterised by long periods without fire, and since it appears that the cool temperate rainforests of Victoria will be most at risk of fire in the not-too-distant future, the potential effects of climate change on cool temperate rainforests are further examined here.

Cool temperate rainforest occurs in areas where fire-free intervals are greater than 400 years (Peel 1999), but with the risk of fire in Victoria predicted to increase by 15–70% in 2050, such long intervals may become a thing of the past (Table 3). Indeed, fire frequency in the Central Highlands of Victoria is already higher than that of the last century (Lindenmayer *et al.* 2011), and one of the largest areas of cool temperate rainforest and cool temperate mixed forest occurs in this region.

Should fire threaten areas in which cool temperate rainforests occur, it is predicted that a positive feedback system will begin wherein with each fire comes greater risk of more fire until, eventually, what we now define as cool temperate rainforest in these key areas will become sclerophyll forest. Once the normally-closed canopy of a cool temperate rainforest is penetrated by fire, it is recolonised by more fire-prone and also more fire-tolerant species such as *Acacia* and *Eucalyptus*. This is known

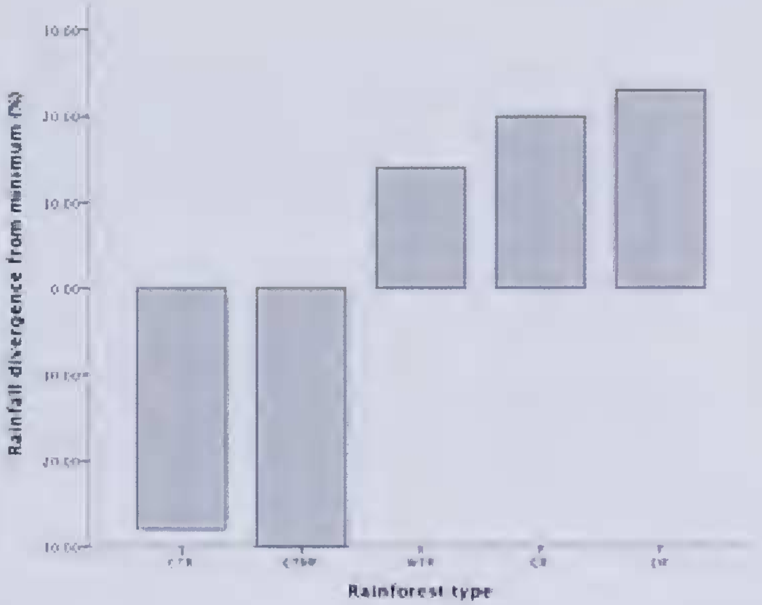

Fig. 1. Average divergence (percentage) from minimum annual rainfall requirement for rainforests of Victoria under a lowere emissions scenario in 2070.

as a landscape 'trap'; ecosystem modification occurs to an almost entirely irreversible extent due to natural and anthropogenic disturbances causing a series of feedback processes (Lindenmayer *et al.* 2011). As previously mentioned, the effects of climate change will threaten the resilience systems of the cool temperate rainforest by reducing humidity, increasing fuel loads and increasing temperatures.

Inland regions such as the North East, Strzeleckis, Central Highlands and parts of East Gippsland are more at risk than coastal rainforest areas such as the Otway Ranges and Wilson's Promontory. The inland rainforest of the Central Highlands, for instance, has coexisted with fire for the last 40 millenia, however the most recent 2500 years has seen fire frequency and intensity increase (Baker *et al.* 2012). Every century, one or two high-intensity crown fires would disturb the rainforest but the damage would be minimal. This is due to the damp and humid resilience of the rainforest and the adjacent *Eucalyptus regnans* F.Muell. forest towering above the rainforest canopy (Baker *et al.* 2012). A high-intensity crown fire in neighbouring *E. regnans* forests affords some protection in that the crown fires will travel slowly and with reduced heat energy toward the crowns of the rainforest species as they stand much shorter than the giant eucalypts (Baker *et al.* 2012). Despite these protective mechanisms, in 2009 47% of the cool temperate rainforest in the Central Highlands of Victoria was burnt (Worley 2012). This suggests that the rainforest's ability to protect itself from fire was reduced due to the intensity and extreme conditions of the burn. In fact, 8.5% of Victoria's cool temperate rainforests were burnt in the 2009 fires, with 50% of the fires classed as 'severe' (Worley 2012). Not only has the intensity of fires increased, the occurrence of major bushfires in Victoria has steadily become more frequent since the 1850s. From 1850 to 1900, Victoria experienced an average of 0.4 major bushfires per decade; from 1900 to 1950, this jumped to an average of 2.4 major bushfires per decade and from 1950 to 2000 the frequency increased again to an average of 3.4 major bushfires per decade (Bryant 2009).

Table 3. Implications of fire on Victoria's cool temperate rainforest due to climate change according to location. (After BOM 2012; Hennessy *et al.* 2005; Anon in *SMH* 2009; Bushfire CRC 2006; CSIRO 2011; Forest encyclopedia 2008).

Areas covered by Rainforest	**Current fire season**	**Predicted fire risk increase with climate change**			**Impacts of climate change on fire**			**Predictions**
		2020	**2050**	**Risk due to location**	**Intensity (heat)**	**Frequency (number)**	**Extent (size)**	
North East	December – February	4–25%	15–70%	High	+	+	+	- High risk of fire due to inland location - Should fire occur, intensity, frequency and its extent would increase due to climate change - Likely to be converted to sclerophyll forest
Otways	December – May	4-25%	15–70%	Low	+	+	+	- Low risk of fire due to proximity to coast - Should fire occur, intensity, frequency and its extent would increase due to climate change - Possibility of being converted to sclerophyll forest
Wilson's Promontory	December – February	4-25 %	15–70%	Low	+	+	+	- Low risk of fire due to proximity to coast - Should fire occur, intensity, frequency and its extent would increase due to climate change - Possibility of being converted to sclerophyll forest
Strzeleckis	December – February	4-25 %	15–70%	High	+	+	+	- High risk of fire due to land location - Should fire occur, intensity, frequency and its extent would increase due to climate change - Likely to be converted to sclerophyll forest
Central Highlands	December – February	4-25 %	15–70%	High	+	+	+	- High risk of fire due to inland location - Should fire occur, intensity, frequency and its extent would increase due to climate change - Likely to be converted to sclerophyll forest
East Gippsland	September – February	4-25 %	15–70%	Low–High	+	+	+	- Low to high risk of fire due to inland and coastal location - Should fire occur, intensity, frequency and its extent would increase due to climate change - Low to high likelihood of being converted to sclerophyll forest

Table 4. The potential effects of climate change on key species of Victoria's cool temperate rainforests. * CH = Central Highlands, EG = East Gippsland, NE = North East, OT = Otways, STRZ = Strzeleckis, WP = Wilson's Promontory. (After Boland *et al.* 1984; BoM and Walsh 1993; Conn 1993; Costermans 2009; Floyd 2008; Francis 1981; Jordan *et al.* 1992; Large and Braggins 2004; Wilkinson and Jennings 1993). N.B. Although these are key species, none are restricted to Cool Temperate Rainforest, or Victoria.

Tree Species	Region*	Rainfall		Fire	Implications	
		Required annual (mm)	2070 prediction at lower emissions (mm)		Plant species	Cool Temperate Rainforest
Acacia melanoxylon	CH, EG, OT, WP	750–1500	820	Requires disturbance to regenerate	Due to regeneration of seed with fire and low water stress, *A. melanoxylon* will persist	Will persist in all regions as part of sclerophyll forest
Atherosperma moschatum	STRZ, WP	1000–2000	870	Limited fire resistance	Due to high risk of fire and high water stress, not likely to persist in habitat	Will recede to the most sheltered pockets, topographically
Eucalyptus obliqua	EG	500–2400	878	Fire tolerant/requires disturbance to regenerate	Due to tolerance of/and regeneration with fire and very low water stress, *E. obliqua* will persist	Will become a dominant of sclerophyll forest in inland locations
Nothofagus cunninghamii	CH, OT, STRZ	1100–2500	820	Limited fire adaptation/ resistance	Due to high fire risk and extreme water stress, not likely to persist in habitat	Will recede to the most sheltered pockets, topographically
Dicksonia antarctica	OT, STRZ, WP	900–1700	875	Fire resistant	At risk due to water stress	May recede to the most sheltered pockets

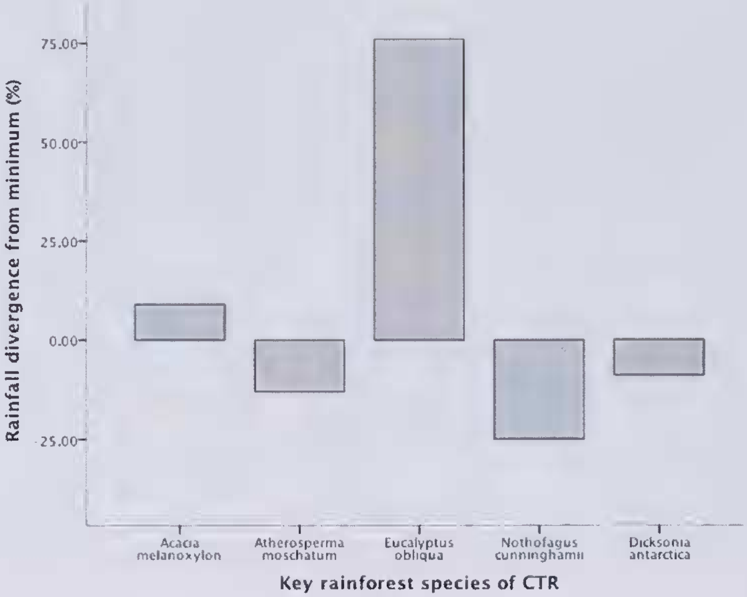

Fig. 2. Average divergence (percentage) from minimum annual rainfall requirement for key rainforest species.

Key species of cool temperate rainforests

To get a better understanding of the effects climate change will have on cool temperate rainforest, it is important to study the key canopy species that constitute the forest. The restrictions on distribution, required versus predicted rainfall parameters and fire adaptations of each species, give key insights into how climate change and broad-scale disturbance, such as fire, may affect each species, and the implications this will have for cool temperate rainforests (Table 4).

In 2070, at lower emissions predictions, *Acacia melanoxylon* R.Br. and *Eucalyptus obliqua* L'Her. will receive annual rainfall that sits well above their minimum requirements; 76% above minimum required annual rainfall in the case of *Eucalyptus obliqua*. By contrast, *Atherosperma moschatum*, *Nothofagus cunninghamii* and *Dicksonia antarctica* Labill. will all receive less rainfall than their current lower thresholds (Table 4; Fig. 2).

Acacia melanoxylon and *Eucalyptus obliqua* are both well adapted to fire and neither species is restricted to cool temperate rainforest or to Victoria. Therefore, should a fire occur, these two species are likely to persist and become dominant in the sclerophyll forest that will eventuate with climate change and increasing fire frequency.

Atherosperma moschatum and *Dicksonia antarctica* are both found in multiple regions as well as beyond Victoria (RBG 2012) and neither is restricted to cool temperate rainforest. Where they occur on coasts, they may be at lower risk to fire but may become less dominant in inland rainforests. *A. moschatum* does, however, have foliage with low flammability due to high moisture and low energy content; studies show that its leaves do not combust until >60% of moisture content is lost (Baker *et al.* 2012). This is in contrast to the leaves of many eucalypt species that will ignite when <40-50% of moisture has been lost (Baker *et al.* 2012).

A key dominant species of Victoria's cool temperate rainforests is *Nothofagus cunninghamii*. This species is restricted to habitats in Victoria and Tasmania. It has some adaptation to fire in its fire-responsive coppice shoots and may have bursts of regrowth after a fire with reproduction occurring either sexually or vegetatively (Howard 1981; Baker *et al.* 2012); however, once a stand of *Nothofagus* is broken up by a fire, the remaining trees no longer have the protection of moisture, low temperatures and limited fuel on the forest floor that the dominant stand had, and are less resistant to the damaging effects of fire (Howard 1981). In the Central Highlands in the 2009 fires, the individuals of *N. cunninghammi* that grew in low numbers as understorey to *E. regnans* or in small patches of rainforest were all killed; Pappas (cited in Baker *et al.* 2012: 187) noted that rainforest taxa did not survive the fires unless they occurred in strips of rainforest that were 50 metres wide or more (Baker *et al.* 2012). These examples demonstrate that the resilience of the species is not necessarily found in the individual. The damaged stand is then likely to burn again, which will continue the process of degradation. Once this positive feedback loop has begun, the fate of the species is compromised.

It is predicted that *Nothofagus cunninghamii* will be receiving 25% less rainfall than its minimum annual requirements. The inability of *Nothofagus* to adapt to lower rainfall levels that came about in the Tertiary period, between 65 and 18 mya, confined it to cooler, wetter areas; so it is predicted that by 2070, the species will be forced to retreat once again to residual areas that are only a fraction of its current extent. *Nothofagus cunninghamii* also requires water, gravity and animals to transport its seeds rather than far-reaching wind or invertebrate vectors (Baker *et al.* 2012). It may persist in Tasmania and in the coastal sites of Victoria, but there is a high possibility that it will recede from its current locations in the inland Strzeleckis and Central Highlands, especially considering its limited dispersal mechanisms.

Conclusion

Factors such as slope, topographic position and competing vegetation must be considered to formulate a more comprehensive prediction of the effects climate change may have on the rainforests of Victoria (Lindenmayer 2009); however, it is still possible to predict the likely fate of Victoria's rainforests based on climate change predictions for 2030, 2050 and 2070.

Should fire, the risk of which is increased by climate change conditions, become more frequent and intense throughout Victoria, cool temperate rainforest will be greatly impacted. The dominant canopy species of Victorian cool temperate rainforests, *Nothofagus cunninghamii*, will be most at risk. Due to climate change, it will experience high water stress and be most susceptible to accumulated effects of increased fire events.

Rainforests, compared to other vegetation types of Australia, are relatively persistent; with the predicted temperature, rainfall and fire regime changes resulting from climate change and continued degradation by humans, Victoria's rainforests may be very different by 2070.

Acknowledgements

I would like to acknowledge the following people for their support and hard work: Dr Maria Gibson for her guidance, knowledge and for answering all my emails; Leah Martini for her support and help with research into fire; and Keryn Riddington for being my editor and for introducing me to rainforests.

References

Anon (2009) Bushfire ferocity linked to climate change, *The Sydney Morning Herald*, 9 February 2009, retrieved 5 August 2012, <http://www.smh.com.au/environment/climate-change/bushfire-ferocity-linked-to-climate-change-20090209-8235.html>

Baker PJ, Simkin R, Pappas N, McLeod A and McKenzie M (2012) Fire on the mountain: A multi-scale, multi-proxy assessment of the resilience of cool temperate rainforest to fire in Victoria's Central Highlands. In *Peopled landscapes: archaeological and biogeographic approaches to landscapes*, pp. 377–389. Ed SG Haberle and B David (ANU E Press: Canberra)

Beadle NCW (1981) *The Vegetation of Australia*. (Cambridge University Press: Cambridge)

Boland DJ, Brooker MIH, Chippendale GM, Hall N, Hyland BPM, Johnston RD, Kleinig DA and Turner JD (1984) *Forest Trees of Australia*. 4 edn, (Thomas Nelson Australia and CSIRO: Melbourne)

Bowman DJS (2000) *Australian Rainforests: Islands of green in a land of fire*. (Cambridge University Press: Cambridge)

Bryant C (2009) Victoria, understanding bushfire: trends in deliberate vegetation fires in Australia, (Australian Government) retrieved 2 October 2013, <http://www.aic.gov.au/documents/7/9/8/%7B7982F769-0EA0-4416-A040-B6056BC0DD06%7Dtbp027_03_vic.pdf>

Bureau of Meteorology (2012) Bushfireweather, (Bureau of Meteorology) retrieved 5 August 2012. <http://www.bom.gov.au/weather-services/bushfire/about-bushfire-weather.shtml>

Bureau of Meteorology and Walsh NG (1993) Climate of Victoria. In *Flora of Victoria, Vol 1, Introduction*, pp. 47–60. Ed DB Foreman and NG Walsh. (Reed International Books (Inkata Press): Melbourne)

Busby JR (1986) A biogeoclimatic analysis of *Nothofagus cunninghamii* (Hook.) Oerst. in southeastern Australia. *Australian Journal of Ecology* **11**, 1–7.

Busby JR and Brown MJ (1994) Southern Rainforests. In *Australian Vegetation*. 2 edn, pp. 131–155. Ed RH Groves. (Cambridge University Press: Melbourne)

Bushfire Cooperative Research Centre (2006) Climate change impacts on fire (Bushfire CRC) retrieved 6 August 2012, <http://www.bushfirecrc.com/sites/default/files/fire-updates/fireupdate-1_2006-06.pdf>

Conn BJ (1993) Natural regions and vegetation of Victoria. In *Flora of Victoria, Vol 1, Introduction*, pp. 79–158. Ed DB Foreman and NG Walsh (Reed International Books (Inkata Press): Melbourne)

Costermans L (2009) *Native trees and shrubs of south-eastern Australia*. 2 Edn. (Reed New Holland: Chatswood, NSW)

Commonwealth Scientific and Industrial Research Organisation (2011) Fireweather (CSIRO) retrieved 5August 2012, <http://www.csiro.au/en/Outcomes/Climate/Adapting/Climate-Change-Fire-Weather.aspx>

CSIRO (2011) Fuel moisture content and bushfire behaviour (CSIRO) retrieved 6 August 2012, <http://www.csiro.au/en/Outcomes/Safeguarding-Australia/FuelMoistureAndBushfires.aspx>

Floyd AG (2008) *Rainforest trees of Mainland South-eastern Australia*. 2 edn. (Terania Rainforest Publishing: Lismore, NSW)

Forest Encyclopedia Network (2008) The Encyclopedia of Southern Fire Science — Fire intensity (Forest Encyclopedia Network) retrieved 6 August 2012, <http://www.forestencyclopedia.net/p/p486/>

Francis WD (1981) *Australian Rain-Forest Trees*. 4 edn. (Australian Government Publishing Service: Yennora, NSW)

Howard TM (1981) Southern Closed Forests. In *Australian vegetation*. 1 edn. pp. 102–119. Ed RH Groves. (Cambridge University Press: Cambridge)

Jarman SJ and Brown MJ (1983) A definition of cool temperate rainforests in Tasmania. *Search*. **14**, 81–87.

Jordan G, Patmore C, Duncan F and Luttrell S (1992) The effects of fire intensity on the regeneration of mixed forest tree species in the Cleer Hill/Mount Wedge Area. (Tasforests, Forestry Commission: Tasmania) retrieved 8 August 2012 http://117.55.239.235/assets/0000/0470/article_3.pdf

Large MF and Braggins E (2004) *Tree Ferns* (CSIRO: Collingwood)

Lindenmayer D (2009) *Forest pattern and ecological process: a synthesis of 25 years of research*. (CSIRO Publishing: Collingwood, Victoria)

Lindenmayer D, Hobbs RJ, Likens GE, Krebs CJ and Banks SC (2011) Newly discovered landscape traps produce regime shifts in wet forests. *PNAS*, **108**, 15887–15891.

Mackey BG, Keith H, Berry SL and Lindenmayer DB (2008) *Green Carbon: The role of natural forests in carbon storage*. (ANU E Press: Canberra)

Peel B (1999) *Rainforests and cool temperate mixed forests of Victoria* (Department of Natural Resources and Environment: East Melbourne)

Read J and Busby JR (1990) Comparative responses to temperature of the major canopy species of Tasmanian cool temperate rain-forest and their ecological significance. II. Net Photosynthesis and Climate Analysis. *Australian Journal of Botany* **38**, 185–205.

Royal Botanic Gardens Melbourne (2012), *Dicksonia antarctica* at the Royal Botanic Gardens Melbourne (RBG) retrieved 14 August 2012, http://www.rbg.vic.gov.au/dbpages/rbgcensus/index.php/census/species_detail/3927

Victorian Climate Change (2008) Climate change in Victoria: 2008 Summary (State Government of Victoria) retrieved 1 August 2012. <http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0020/73172/DSEstatesummaryWEB.pdf>

Victorian Climate Change (2011a) Climate change in the Corangamite region (State Government of Victoria) retrieved 1 August 2012. <http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0017/73070/Corangamite_WEB.pdf>

Victorian Climate Change (2011b) Climate change in East Gippsland (State Government of Victoria) retrieved 1 August 2012, http://www.climatechange.vic.gov.au/ _data/assets/pdf_file/0003/73119/EastGippsland_ WEB.pdf

Victorian Climate Change (2011c) Climate change in the North East region (State Government of Victoria) retrieved 1 August 2012, http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0020/73118/NorthEast_WE B.pdf

Victorian Climate Change (2011d) Climate change in the Port Philip and Westernport region (State Government of Victoria) retrieved 1 August 2012, <http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0003/73029/PPWP_WEB .pdf>

Victorian Climate Change (2011e) Climate change in West Gippsland (State Government of Victoria) retrieved 1 August 2012, http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0013/73120/WestGippsland _WEB.pdf

Wilkinson G and Jennings S (1993) Survival and recovery of *Eucalyptus obliqua* Regeneration following Wildfire (Tasforests, Forestry Commission: Tasmania) retrieved 8 August 2012. http://www.forestrytas.com.au/assets/0000/0439/tf_5_article_1.pdf

Worley M (2012) *Impacts of the 2009 Kilmore East–Murrindindi bushfires on cool temperate rainforest in the Victorian Central Highlands: Black Saturday Victoria 2009 – Natural values fire recovery program* (Department of Environment and Sustainability: Melbourne).

Received 21 November 2013; accepted 19 June 2014

One Hundred Years Ago

Plant distribution in the Healesville District

BY REGINALD KELLY

Eucalyptus obliqua is veritably a messmate to all those mentioned, being found in association with them, and usually the dominant partner, from the lowest to the highest ground. It is found on the river banks, sometimes hanging over the water in almost willow-like form, and at the tops of the mountains as a straight-trunked, magnificent timber tree.

From *The Victorian Naturalist* **XXXI**, p. 58, August 6, 1914